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The influence of using biogas digesters on family energy consumption and its economic benefit in rural areas—comparative study between Lianshui and Guichi in China

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Abstract

The construction of biogas digesters has improved the family energy consumption structure, promoted the development of livestock breeding and farm production in the countryside. Through the comparative study of the questionnaires filled out by individual families in Lianshui, Jiangsu Province and Guichi, Anhui Province, we figured out the different effects of biogas digesters in different areas on household energy consumption and their benefits to economy and environment.

Keywords: Biogas digester; Biomass; Renewable energy; Energy consumption; Rural energy

Contents

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1. Introduction

The construction of biogas digesters in China has made well-acknowledged achievements: biogas has been widely used as fuel and has contributed a lot to the improvement of rural environment and the development of rural economy. Since the reform and opening of China in 1978, the construction of biogas digesters has been carried out steadily; now that the agriculture in China has stepped into a new development stage, the construction has showed its evident effects on promoting the readjustment of agricultural structure, stimulating crop production and improving the environment. Various researches have proved that the construction of biogas digesters has had positive effects on economy, society, ecology and environment [1–7]. But there has not been any comparative study among different typical areas, which is also crucial to the selectivity of the construction and to the objective evaluation of its benefits. Such study will provide data and basis for the development of biogas digesters and for those projects to improve rural economy and environment.

2. Data and methods

Lianshui, Jiangsu, located in the east of Xu Huai Plain, is underdeveloped and depends mainly on agriculture. Guichi, Anhui, is located at the south bank of the lower reaches of Yangtze River, on which mountains, hills and low-lying fields are distributed hierarchically; the south Guichi is featured with low mountains and produces lumber and tea; the mid Guichi is featured with hills and fields and turns out good crops, cooking oil, hemp and mulberry, etc.; the north is mainly low-lying fields and there are woods of several score meters' width along the river to prevent flood, and large quantities of crops and lotus roots are produced here, which entitles this part "the barn of Guichi".

Lianshui, located on a plain, is typical of using straw and stalk as fuel, whereas Guichi, in a hilly area, is typical of using firewood as fuel. Both places have undertaken the national projects of Public Energy Facilities in Miniature in the Countryside and have constructed a certain scale of biogas digesters in certain sample villages. From July to August, 2004, trained investigators visited 356 families in Lianshui and 340 ones in Guichi and conducted specially designed questionnaires. There are 59 questions concerning information about basic family conditions, energy consumption and the construction of biogas digesters; the subjects are usually the housemasters or housewives in the families. We used the software package of social science (SPSS) to process and analyze the acquired data.

Table 1 displays the basic family conditions in Lianshui and Guichi, which implies no big difference in resident population, labor force, cultivated area and harvest. The families

Table 1
The nature of the economy in Liangshui County and Guichi County in 2003

	Liangshui county	Guichi county
Number of resident persons per household	4.29	4.13
Number of labor force per household	2.21	2.43
Total family income (yuan)	9119.66	21317.65
Cultivated area per household (hm^2)	0.413	0.363
Grain harvest per household (kg)	1896.70	1688.31
Number of pigs per household	4.05	1.53

Table 2
The sample demographic characteristics

Number of persons per household		1	2	3	4	5	6	⩾7	Total
Liangshui County	Sample size	3	19	65	129	91	30	7	356
	%	0.8	5.3	18.3	36.2	25.6	8.4	2.0	100
Guichi County	Sample size	3	6	85	146	68	23	7	340
	%	0.9	1.8	25.0	42.9	20.0	6.8	2.7	100

in Guichi have higher total family income and electricity consumption than those in Lianshui; Lianshui raise much more pigs than Guichi. There is no distinctive difference in rural family population distribution in these two places. The living conditions in Guichi are obviously higher than that of Lianshui. Table 2 gives the sample demographic characteristics.

3. Results and analysis

3.1. Comparison on energy consumption

The per capita family energy consumption in 2003 is 205.30 kgce (1kgce = 29.31 MJ) in Lianshui and 232.98 kgce in Guichi (Table 3). The energy consumption in both places depend mainly on non-commercial energy; commercial energy in Lianshui, primarily electric power and certain coal and charcoal, takes up 25.48%, while in Guichi, various commercial energy takes up only 19.66%. According to the specific conditions of the two places, we suppose the conversion efficiency of stalk and straw and firewood to be 18%, coal and charcoal 22%, biogas and liquefied gas 60%; thus in Lianshui, the per capita effective heat in rural family energy consumption is 56.71 kgce, the proportion of commercial energy in effective heat is 7.73%; in Guichi, per capita effective heat is 62.87 kgce, the proportion of commercial energy 9.7%. Therefore, Guichi consumes a higher per capita effective heat over Lianshui. Considering that Lianshui raises more pigs, which demands more fuel to cook the feeding mash, we believe that Lianshui actually has a relatively lower energy consumption.

Table 3
Per capita rural household energy consumption in Liangshui County and Guichi County in 2003 (kgce)

			Firewood	Straw	Biogas	Coal	Kerosene	LPG	Electricity	Total
Liangshui county	Lighting		—	—	0.07	—	0.01	—	31.98	32.06(15.62)
	Cooking		47.31	25.06	42.91	12.37	—	1.82	3.71	133.18(64.87)
	Breeding		8.87	6.04	4.18	0.37	—	0.01	—	19.47(9.48)
	Heating water		—	5.75	11.77	1.56	—	0.06	—	19.14(9.32)
	Remainder		—	0.92	0.11	0.42	—	—	—	1.45(0.71)
	Total		56.18	37.77	59.04	14.72	0.01	1.89	35.69	205.30(100.00)
		/%	27.36	18.40	28.76	7.17	0.00	0.92	17.39	100.00
Guichi County	Lighting		—	—	—	—	—	—	36.13	36.13(15.51
	Cooking		129.35	—	47.21	—	—	9.19	0.44	186.19(79.92)
	Breeding		1.54	—	2.29	—	—	—	—	3.83(1.64)
	Heating water		—	—	6.73	—	—	0.05	—	6.78(2.91)
	Remainder		—	—	0.05	—	—	—	—	0.05(0.02)
	Total		130.89	—	56.28	—	—	9.24	36.57	232.98(100.00)
		/%	56.18	—	24.16	—	—	3.97	15.69	100.00

Electrical energy includes the energy required to produce electricity (1 kWh = 0.392 kgce).

There is a big difference in the energy consumption structure between the two places. Lianshui depends mainly on biogas, firewood, stalk and straw, whereas Guichi depends more on firewood and biogas. The difference is chiefly due to the local energy resources and the availability of energy. Since Guichi peasants can acquire a great quantity of firewood, they prefer firewood to straw and stalk because it is more convenient to use the former. The consumption of biogas and electric power in both areas is close.

The ultimate use of the energy primarily goes to cooking and lighting, which takes up 64.87% and 15.62% of the total energy consumption in Lianshui, and 79.72% and 15.51% in Guichi.

3.2. Comparison in energy consumption between families with and without biogas digesters

In both areas, compared with those families without biogas, those who have built biogas digesters consume much less energy. The ratio of the energy consumption by those with digesters over those without is 0.589(190.32/323.02) in Lianshui and 0.587(220.72/375.94) in Guichi (see Tables 4 and 5). This shows that when the need of effective energy is satisfied, the high heating efficiency of biogas saves more low-heating-valued fuel; those families with biogas digesters consume only less than 60% energy of those without.

Biogas primarily takes the place of firewood and straw and stalk in Lianshui. The per capita consumption of straw and stalk by those families without biogas is 112.27 kgce and by those with is 28.10 kgce; the per capita consumption of firewood is 143.00 and 45.50 kgce, respectively. Biogas also replaces a small amount of coal and charcoal and liquefied petroleum gas (LPG). Though most rural families have LPG, they seldom use it since they think biogas is more economical and can replace LPG in a sense; therefore they usually prefer to use biogas and only use LPG in emergent cases. Only a few families with relatively high income use a lot of LPG in their daily life. In Lianshui county, rural families

Table 4
Per capita rural household energy consumption between household with biogas digester and household without biogas digester in liangshui county in 2003 (kgce)

		Straw	Firewood	Biogas	Coal	Kerosene	LPG	Electricity	Total
Household with biogas digester	Lighting	—	—	0.19	-	0.01	-	32.49	32.69
	Cooking	18.25	36.10	48.19	10.45	—	1.44	3.75	118.18
	Breeding	5.42	9.40	4.70	0.35	—	0.01	—	19.88
	Heating water	3.92	—	13.21	1.42	—	0.03	—	18.58
	Remainder	0.51	—	0.01	0.47	—	-	—	0.99
	Total	28.10	45.50	66.30	12.69	0.01	1.48	36.24	190.32
Household without biogas digester	Lighting	—	—	—	—	0.07	—	27.81	27.88
	Cooking	80.20	138.42	—	27.95	—	4.96	3.38	254.91
	Breeding	11.12	4.58	—	0.50	—	—	—	16.20
	Heating water	20.55	—	—	2.75	—	0.33	—	23.63
	Remainder	0.40	—	—	-	—	—	—	0.40
	Total	112.27	143.00		31.20	0.07	5.29	31.19	323.02

Table 5
Per capita rural household energy consumption between household with biogas digester and household without biogas digester in Guichi County in 2003 (kgce)

		Firewood	Straw	Biogas	Coal	Kerosene	LPG	Electricity	Total
Household with biogas digester	Lighting	—	—	—	—	—	—	35.30	35.30
	Cooking	114.03	—	50.87	—	—	8.90	0.34	174.14
	Breeding	1.52	—	2.48	—	—	—	—	4.00
	Heating water	—	—	7.22	—	—	0.01	—	7.23
	Remainder	—	—	0.05	—	—	—	—	0.05
	Total	115.55	—	60.62	—	—	8.91	35.64	220.72
Household without biogas digester	Lighting	—	—	—	—	—	—	46.18	46.18
	Cooking	314.42	—	—	—	—	12.59	0.43	327.44
	Breeding	1.83	—	—	—	—	—	—	1.83
	Heating water	—	—	—	—	—	0.49	—	0.49
	Remainder	—	—	—	—	—	—	—	—
	Total	316.25	—	—	—	—	13.08	46.61	375.94

are used to using coal and charcoal in winter; though the output is low in winter, biogas is still available if a warm temperature is ensured. According to the data in Table 4, biogas also replaces a small amount of coal and charcoal. Since the energy consumption in Guichi depends primarily on firewood, biogas replaces a large amount of firewood here; the consumption of firewood in two kinds of families is 314.42 and 114.03 kgce, respectively.

Table 6 demonstrates the comparison in effective heat in cooking, breeding, heating water by using different energy between families with and without biogas digesters, which

Table 6
Per capita rural household energy consumption by energies between household with biogas digester and household without biogas digester in 2003 (kgce)

		Firewood	Straw	Biogas	Coal	LPG	Total
Liangshui county	Household with biogas digester	5.06	8.19	39.78	2.79	0.89	56.71
	Household without biogas digester	20.21	25.74	—	6.86	3.17	55.98
Guichi county	Household with biogas digester	—	20.80	36.37	—	5.35	62.52
	Household without biogas digester	—	56.93	—	—	7.85	64.78

Table 7
The benefit for development of household biogas digesters (RMB/ household)

	Liangshui county	Guichi county
Reducing expenses on medicine	13.40	41.13
Reducing expenses on pesticide	11.62	34.82
Reducing expenses on chemical fertilizer	35.87	44.41
Net income from the marsh liquid	35.90	53.66
Net income from the dregs	39.75	47.29
Total	136.54	221.31

implies no big change. This shows that families do not acquire more effective heat by using biogas. When the basic need for effective energy is met, the effective heat provided by biogas replaces that provided by stalk and straw, firewood, a small amount of LPG and coal and charcoal.

3.3. Analysis on economic benefits of building biogas digesters

It is difficult to evaluate the economic benefits of utilizing biogas. As for the peasants, it can be categorized into direct and indirect economic benefits.

Direct economic benefits refer to those brought about by the biogas fuel, and are figured out by using opportunity cost method. Since biogas is a kind of high-quality fuel and using it is as convenient as using LPG, we can use the value of the LPG that is of the same amount of biogas to substitute its benefits. Owing to the climate, biogas digesters in Lianshui produce gas for 9–10 months; the yearly output of gas from a 8 m^3 digester is about 370 m^3 in Lianshui and 480 m^3 in Guichi. Since the price of LPG is 4.6 yuan/kg, by using the above method, we can figure that the economic value of the yearly output of a biogas digester is 703 yuan in Lianshui and 912 yuan in Guichi. If we only consider the benefit of producing gas, the interior earning rate of the construction project in Lianshui from the peasants' aspect is 68.67%; even if we calculating the benefits by using biogas as a substitute for coal and charcoal, the interior earning rate is 13.57%, which still implies profits.

However, other economic benefits brought about by biogas cannot be evaluated easily. We designed questions in the investigation as for the benefits that the construction of

biogas digesters brings in reducing expenses on medicine, pesticide and chemical fertilizer, and in getting net income from the marsh liquid and dregs. The result (see Table 7) shows that the total benefits in the above five aspects amount to 136.54 yuan in Lianshui and 221.31 yuan in Guichi.

4. Conclusions

Through the investigation, we have found evident difference in family per capita energy consumption between Lianshui and Guichi. The construction of biogas digesters has reduced family energy consumption by more than 40%, which mainly comes from biotic substances and thus benefits the environment greatly. The research also indicates that building the digesters has not increased the family per capita effective heat; the gas produced by the biogas digesters is a high-quality fuel and is quite beneficial; the yearly benefits such as cutting back medical expenses are around 100–200 yuan, which varie in different areas.

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